REPORT ON
PUNCHING LOAD-CARRYING CAPACITY OF SLABS REINFORCED WITH HIGH-STRENGTH STARK STEEL RE BARS

PHASE-3

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Disclaimer
This report summarizes the test results of slabs reinforced with STARK steel rebar subjected to punching shear load.

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1. INTRODUCTION

This study explores the performance of the use of high-strength steel rebars for on-grade slab applications. The load-carrying capacity of square slabs of size 1 m x 1m reinforced with high-strength Stark steel rebars under punching shear loading is evaluated. High-strength Stark steel rebars are manufactured and supplied by Somani wires Ltd, Hyderabad. Two slab thicknesses and two different spacing of rebars were considered as test parameters.

2. EXPERIMENTAL PROGRAM

The test matrix for the punching shear load test is shown in Table 1. The parameters considered are the spacing of reinforcement and the depth of the slab. Two types of spacing were considered (150 mm and 200 mm) with two different depths (150 mm and 170 mm).

Table 1:Details of test specimens

Designation of Specimen	Depth (D) (mm)	Spacing (S) (mm)	Length (L) (mm)	Amount of reinforcement (kg/m^2)
P_D170_S150_S1	170	150	1000	2.30
P_D170_S150_S2	170	150	1000	2.30
P_D170_S200_S1	170	200	1000	1.65
P_D170_S200_S2	170	200	1000	1.65
P_D150_S150_S1	150	150	1000	2.30
P_D150_S150_S2	150	150	1000	2.30
P_D150_S200_S1	150	200	1000	1.65
P_D150_S200_S2	150	200	1000	1.65

Note: *Designation defined as:* ***P*** *means punching shear test,* ***D*** *means depth of the slab,* ***S*** *means spacing of the reinforcement,* ***S1 and S2*** *are the specimen-1 and specimen-2.*

2.1. Materials and mix proportions

The concrete mix of grade M25 was designed using IS 10262 and IS 456 code recommendations. Ordinary Portland cement (OPC) of 53 grade conforming to IS 4031-1988 was used to develop the design concrete mix. The specific gravity of cement was 3.15. Locally available natural sand was used as fine aggregate. The fine aggregate corresponded to Zone-III grading requirement of IS 383-1970. The specific gravity of fine aggregate was 2.7 and its fineness modulus was 2.2. The locally available crushed granite rock with a specific gravity of 2.79 was used as coarse aggregate and a nominal size of 10 mm. The mix proportion of cement, fine and coarse aggregates used in the mix design were 1:2.24:3.31 by weight. A water-to-cement ratio of 0.55 was used throughout the entire mix. High-strength Stark steel rebars with yield strength of 1700 MPa was adopted. The mechanical properties of the steel rebars used are given in Table 2.

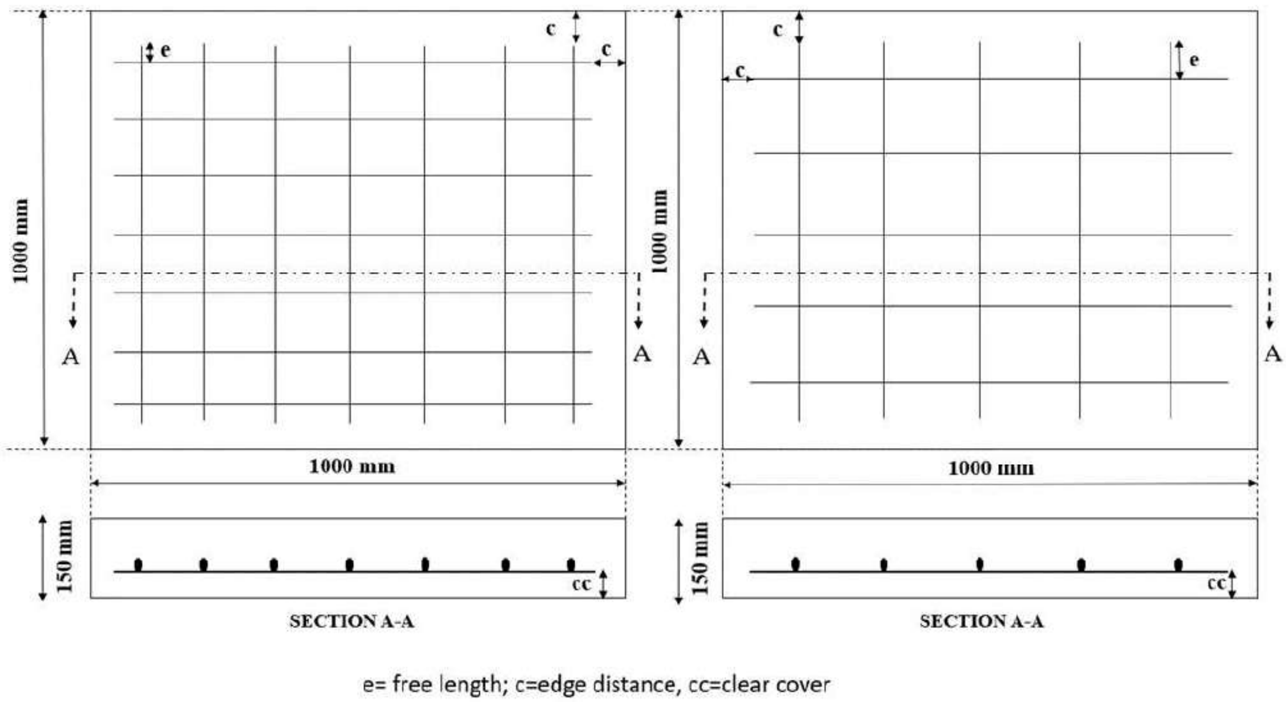
Table 2:Mechanical properties of steel rebars

Material	Diameter (mm)	Yield stress (MPa)	Modulus of Elasticity (GPa)	Elongation (%)
STARK Steel Rebar	5.2	1776	195	5.37

Summary of Phase 1 Tension test on STARK steel rebars based on five samples are as follows:

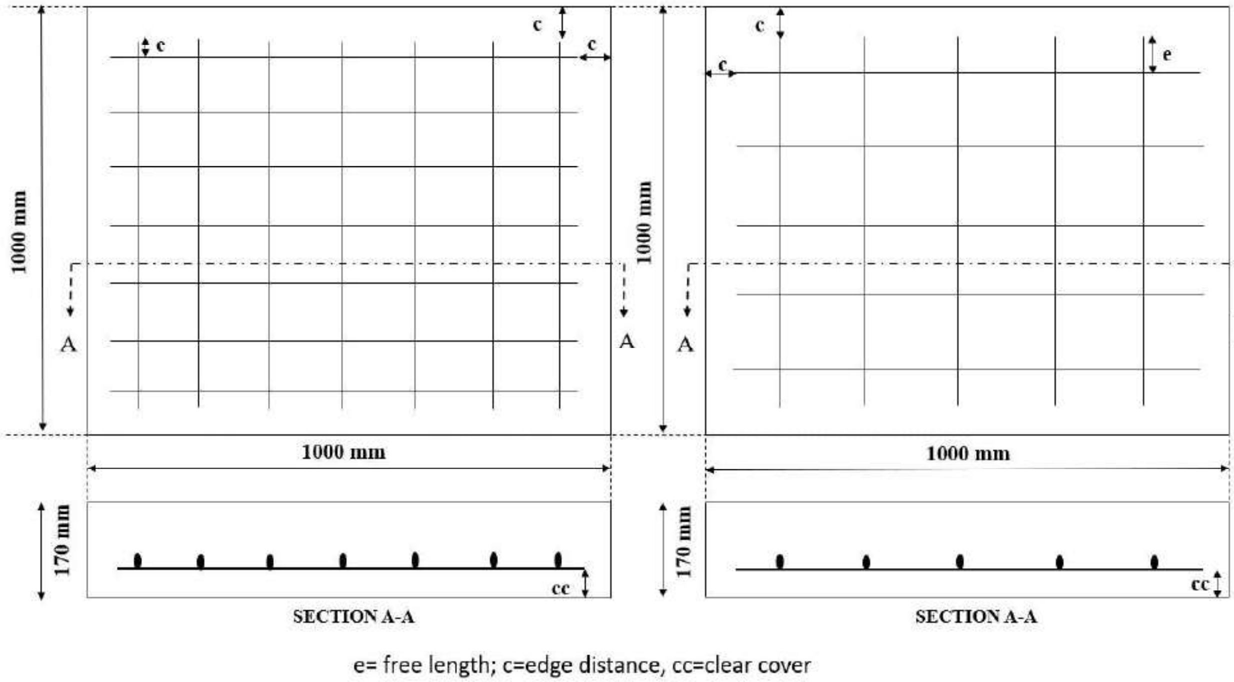
- ✓ The average yield load is 37.7 kN and corresponding yield strength is 1776 MPa.
- ✓ The average ultimate load is 40.8 kN and corresponding ultimate strength is 1921 MPa.
- ✓ The elastic modulus is 195 MPa.
- ✓ The average strain at failure of 5.37%.

Slabs of length 1000 mm and breadth 1000 mm of varying depths were cast with two different spacing mats. Reinforcement details of slabs are mentioned in Figure 1 & Figure 2.



Reinforced with Stark steel @ 150mm c/c	Reinforced with Stark steel @ 200 mm c/c
Bar length=950mm	Bar length=950mm
e=25 mm	e=75 mm
c=25 mm	c=25 mm
cc=25 mm	cc=25 mm

Figure 1:Reinforcement detailing for the square slab of 150mm depth



Reinforced with Stark steel @ 150mm c/c	Reinforced with Stark steel @ 200 mm c/c
Bar length=950mm	Bar length=950mm
e=25 mm	e=75 mm
c=25 mm	c=25 mm
cc=25 mm	cc=25 mm

Figure 2:Reinforcement detailing for square slab of 170mm depth

2.2. Specimen Preparation

The wooden moulds were prepared for specimens to be cast, as shown in Figure 3b. The reinforcing mats with two different spacings were placed at a clear cover of 25mm for all specimens. The materials of the concrete mix were poured into a concrete mixer, and mixing was done for 5 minutes. The slump test (Figure 3a) was done to check the workability of the mix. Slump was found to be in the range of 40 to 60 mm. The concrete mixture was poured into the molds and vibrated for proper compaction. Companion concrete cubes were also cast to determine the mechanical properties. Mean strength of concrete at 28 days are reported in Table 3.

Table 3:Mechanical properties of concrete

Properties	Mean (MPa)	Standard deviation (%)
Compressive strength	29.2	5.94
Modulus of Elasticity	27000	5.02

Figure 3: a) Slump test b) Wooden mould

2.3. Testing of specimens

The specimens were tested using servo-controlled actuator of 1000 kN capacity using digital closed-loop control. The test set-up of the specimen and instrumentation used are shown in Figure 4. The mid-span displacement was measured using a linear variable differential transducer (LVDT). Strain variation in the reinforcement bar has been measured from the strain gauges attached to the rebars. The Load, displacement, and time results are simultaneously acquired through a data acquisition system.

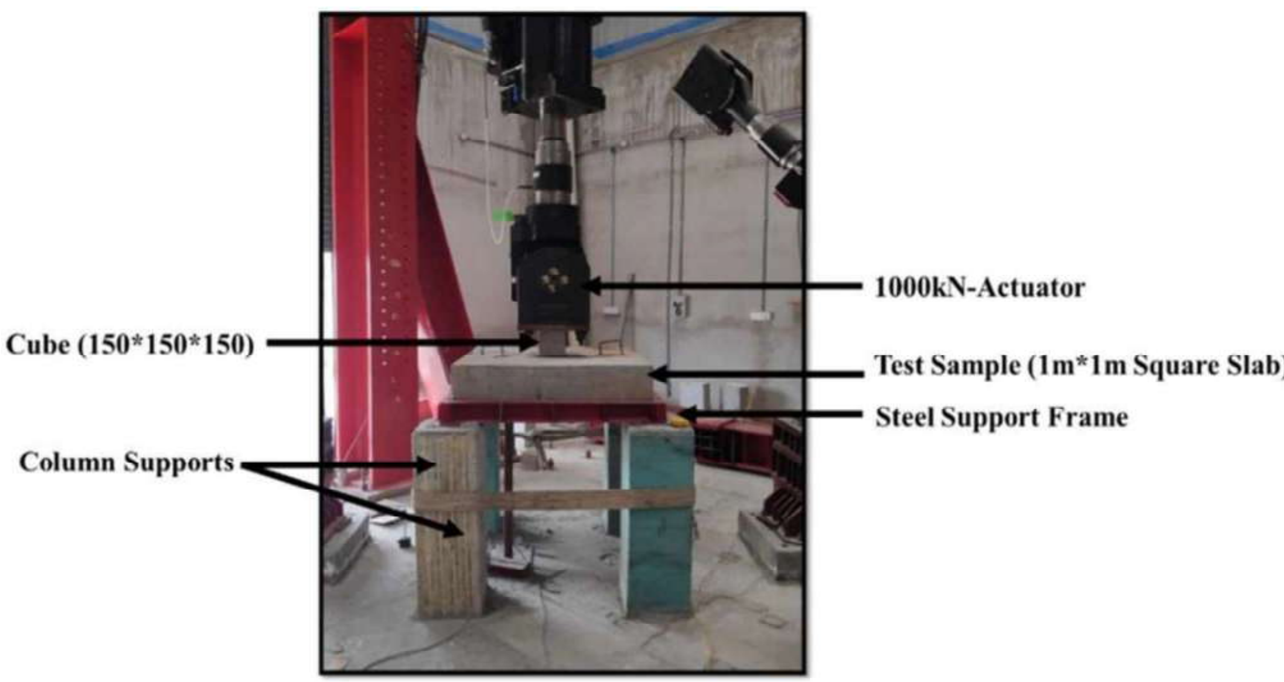


Figure 4: Punching shear test set-up

3. RESULTS AND DISCUSSIONS FROM MECHANICAL TESTING

The experimental data such as Load vs mid-span displacement and strain values acquired during the tests are analyzed. The Load vs displacement behavior and the crack pattern are shown in the following figures.

3.1 Punching shear test

SPECIMEN: P_D170_S150

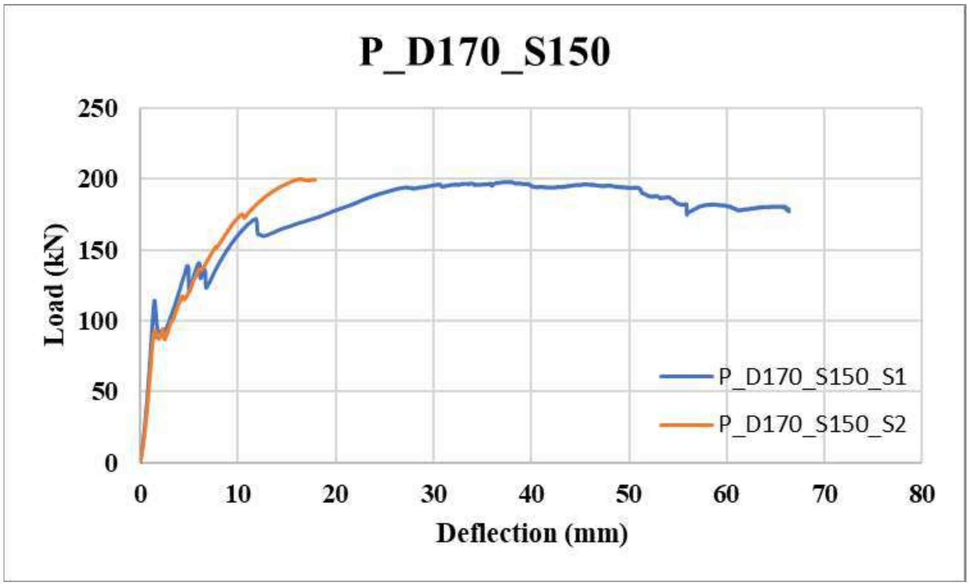


Figure 5: Load vs Deflection response of the specimen D170_S150 under punching loading

Table 4:Average values for D170_S150 in tonnes

S. No	Sample ID	Cracking Load (tonnes)	Average Cracking Load (tonnes)	Ultimate Load (tonnes)	Average Ultimate Load (tonnes)
1.	D170_S150_S1	11.52	10.37	20.12	20.20
2.	D170_S150_S2	9.24		20.28	

Figure 6:Failure mode of the specimen D170_S150

SPECIMEN: P_D170_S200

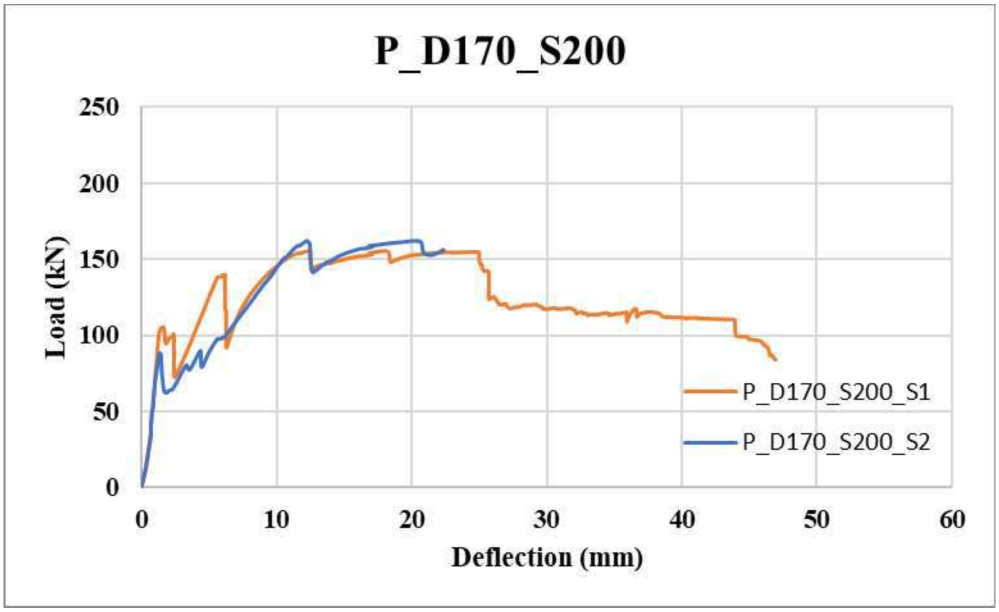


Figure 7: Load vs Deflection response of the specimen D170_S200 under punching loading

Table 5:Average values for D170_S200 in tonnes

S. No	Sample ID	Cracking Load (tonnes)	Average Cracking Load (tonnes)	Ultimate Load (tonnes)	Average Ultimate Load (tonnes)
1.	D170_S200_S1	8.80	9.75	16.44	16.03
2.	D170_S200_S2	10.70		15.62	

Figure 8: Failure mode of the specimen D170_S200

SPECIMEN: P_D150_S150

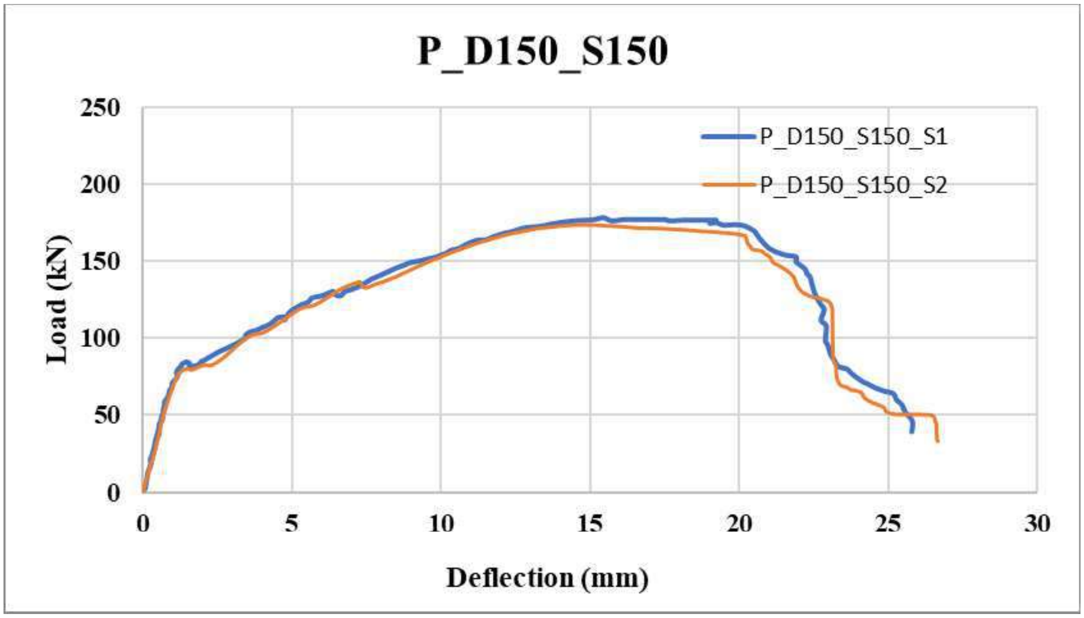


Figure 9: Load vs Deflection response of the specimen D150_S150 under punching loading

Table 6:Average values for D150_S150 in tonnes

S. No	Sample ID	Cracking Load (tonnes)	Average Cracking Load (tonnes)	Ultimate Load (tonnes)	Average Ultimate Load (tonnes)
1.	D150_S150_S1	8.34	8.45	18.13	18.15
2.	D150_S150_S2	8.57		18.18	

Figure 10: Failure mode of the specimen D150_S150

SPECIMEN: P_D150_S200

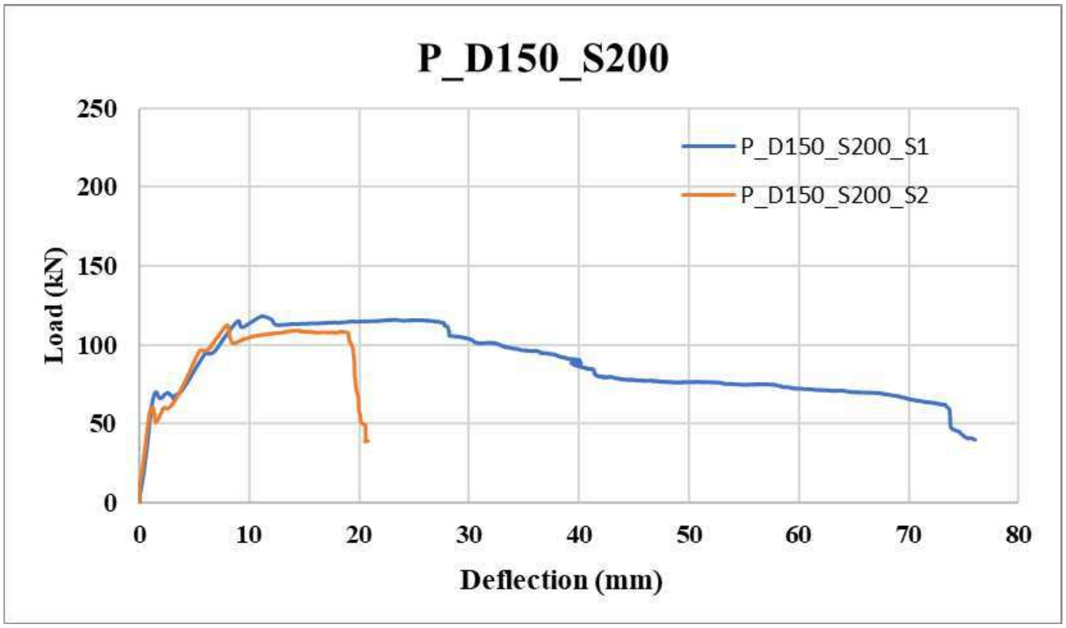


Figure 11: Load vs Deflection response of the specimen D150_S200 under punching loading

Table 7:Average values for D150_S200 in tonnes

S. No	Sample ID	Cracking Load (tonnes)	Average Cracking Load (tonnes)	Ultimate Load (tonnes)	Average Ultimate Load (tonnes)
1.	D150_S200_S1	6.23	6.63	11.86	11.96
2.	D150_S200_S2	7.03		12.06	

Figure 12:Failure mode of the specimen D150_S200

OBSERVATIONS:

- Stark Steel demonstrated satisfactory ductility performance and commendable load-carrying capacity under punching loading, without any strand rupture observed until the ultimate load.
- The steel's elongation of 5.4%, measured from a previous tensile test, suggests its good formability and ability to deform before breaking.
- Based on the experimental results, Stark Steel is suitable for applications requiring high strength and resistance to mechanical stress.
- The observed crack pattern in the specimens indicates that the slab of Stark Steel exhibits a high level of indeterminacy, making it advantageous for applications where structural redundancy is essential for safety and reliability.

4. SUMMARY

- The study investigated the performance of slabs reinforced with high-strength Stark steel rebars under punching loading. Slabs of two different depths with different spacing were considered.

REFERENCES

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